Science in Primary Schools

This discussion paper offers some comments on the variety of ways in which children of primary school age can be taught to think scientifically and some suggestions for the consideration of Local Education Authorities and Heads.

1

Science and the curriculum

The intellectual processes of science

Science with its emphasis on the study of the environment and concern for direct observation and practical investigation matches what we know of how children best learn. It can assist pupils to bring questioning minds to their experience of things around them. The teaching of science in primary schools should seek to develop the processes of scientific thinking such as:

observing
pattern seeking
explaining
experimenting
communicating
applying

Observing does not mean simply looking and recording. It means being alert to the many features that may be observable and not only to those that are most obvious. Children studying trees, might include the sycamore. Certain features spring immediately to mind — the general shape of the tree, its size, the shape of its leaves, and its method of seed dispersal. The helicopter action of the seeds is fascinating in itself but alert children may also notice the distribution of seeds on the ground, the distance they travel from the tree and whether or not they seem to travel further in some directions than in others. They might be led on to speculate about the growth of sycamore seedlings and their distribution or to conduct experiments with the seeds, dropping them from various heights and in various conditions to observe their flight. They might try making a working model of a sycamore seed. They are then taking the first steps along the road to the formulation of a pattern in which their observations are related to one another so that those factors that are common, and those that are not common, can be seen and distinguished. In part of the Schools Council Science 5-13 Project, children make a model siege engine and, in playing with it, learn something about projectiles. They can discover the conditions that produce maximum range and go on to ask whether this is part of a larger pattern concerning the flight of projectiles or whether it is peculiar to this model. At a more sophisticated level they might be led to ask whether some features of the operation of the model are part of a common pattern while others are not.

Explaining an observed pattern of events is an important part of true scientific activity. There may be several possible explanations for a particular pattern and children may not always be able to determine the correct one immediately, although they may very well have ideas about which is most likely to be correct. Two ten year old boys attached a model soldier to a pulley and ran the pulley down an inclined string. They used different heights and lengths for the string to make the model go faster. They then hit on the idea of attaching another long string to pull the model back to the starting point. The model went more slowly and less far after being released. The boys could offer several possible explanations in this order: the string was an extra weight; pulling the string after it caused the model to slow down; the friction of the additional string on the ground impeded the model.

To arrive at a clearer idea of the most likely explanation they needed to carry out some experiments to test the various possibilities. They tried removing the extra string but attaching an equivalent weight to the model; they tried attaching a number of short strings of equivalent total length; and they tried holding the string up off the ground as the pulley descended. They decided that friction was the over-riding factor. To carry out these experiments successfully meant careful thought about their design and about which factors should be varied and which kept the same. Experimenting always involves careful design, a clear basis of observation, and knowledge. They could well have used their knowledge to design a pulley transport system with particular characteristics such as to carry a particular weight at a particular speed. This would have been an example of their growing awareness of technology and technological processes.

Scientific facts and principles are capable of expression in a variety of ways — in speech or writing, pictorially or graphically, or by the use of number or mathematical relationships. For example, pupils who have hamsters in the classroom can learn about them through handling them and talking about them but they will learn more if they can also draw or make a painting of them, measure their lengths, plot graphs of their growth, and tabulate their increase in weight against their intakes of food. Understanding is strengthened through having to make the effort required to produce a satisfactory description or statement.

Given sufficient opportunity to think scientifically, pupils are able to apply ideas and knowledge to problems new to them. A general knowledge of the needs of plants will enable them to suggest reasons why certain wild plants appear in some places and not in others. The boys who found difficulty with friction in one situation will be likely to recognise it in another and perhaps suggest ways of overcoming it or using it.

The content of science

It is impossible to develop a mode of thought without some basic content about which to think. Or, to put it another way, we cannot be certain we are thinking scientifically unless we have a substantial experience of thinking about matters that are recognisably scientific. There are certain fundamental facts and ideas that pupils must meet and grasp if they are to make any significant progress in their studies. The teacher must be very clear about which scientific concepts are to be used or devloped in any particular piece of work so that it may be appropriate to the age and development of the pupils. There are, too, some scientific ideas that call for a carefully chosen sequence in what is done if concepts are to be thoroughly grasped and progress is to be made from year to year. The implications of this important point are further explored in Chapter 2. Aspects of science that children should meet in the primary school include:

The study of living things and their interaction with the environment
Materials and their characteristics
Energy and its interaction with materials
Forces and their effects.

The approach can be made through a variety of activities but it is important to understand which part of the activity contributes to the science and at what level. It will often be necessary to supplement a particular activity beforehand or afterwards (or possibly both) so that ideas can be thoroughly grasped. To move towards an understanding of forces, pupils first need a considerable amount of simple, everyday experience of forces and what they can do. Having gained some rough and ready ideas, both qualitative and quantitative (eg roughly twice the force produces roughly twice the effect), they are then ready to apply forces to materials in more systematic ways and to study examples of the application of forces.

Systematic enquiry

A generalised school activity can be extremely useful it if is well planned. Preparation is needed beforehand, the teacher and the children need to know what is to be studied during the activity, and sufficient follow-up is necessary to ensure learning. The point to be emphasised is that science is being done when the pupils are carrying out a systematic enquiry, but not all activities meet this requirement. For example a visit to the countryside or the seashore can offer many possibilities — geographical, historical, artistic, scientific and so on. The children may decide to study birds. They may draw and paint pictures of birds, make collections of feathers, bring to school collections of birds' eggs which they have been given (but, it is to be hoped, not made themselves). They may find information about birds and broaden their investigation to aeroplanes. Pupils often find this kind of work interesting and rewarding and it has a part to play in improving their skills in classifying, assembling information and in writing and speaking. However, it is very easy for pupils to do a great deal of work on birds with almost nothing that could be called scientific being included. To draw or paint birds, to make collections about them, to assemble pictures, even to read and write about them may not be at all scientific. A systematic enquiry might involve looking not only at the birds themselves but at their mode of living; investigating their food preferences and the way they are adapted to their habitat; it might include comparison between birds of different types, different habits and different distributions geographically and numerically. Explanations might be sought for the appearance of certain birds in certain places and for seasonal variation in the bird population. To take another example, this time from technology: the building of a model bridge is not in itself either scientific or technological. But scientific and technological development is taking place when a sustained investigation is being made of forces and structures, when pupils are asking questions and seeking answers through experiment or in books, and when what they have learned begins to influence their design of the model bridge.

Teaching and learning

For science to be taught effectively teachers must have an understanding of its requirements and a knowledge of its content, particularly of those facts and concepts that are of fundamental importance. They need to be able to strike the right balance between these factors and the time necessary to ensure that for each child there is some recognisable structure in his scientific thinking and in the scientific content presented to him so that he has at least a patchwork quilt and not just a rag-bag of material. Teachers also need to understand the importance to science of experimental investigation. Very few teachers in their own science education were given the experience of designing or carrying out their own experiments and this probably accounts for the difficulty that so many of them say have with this aspect of the work. Nevertheless, experimenting is an essential component of science and experience has shown that, given advice and support, teachers find the obstacle surmountable. There is certainly a great deal of evidence to suggest that children do not have great difficulty with the process although it has to be recognised that, as with observation and pattern-seeking, there will be a steady progression with age and experience. For example, some six year old children tested their ideas on lifting weights with a lever by changing the position of a block of wood under a plank until they could lift their teacher by pressing on the other end of the plank with one foot. Some nine and ten year olds examined the relationship much more systematically by hanging weights from a strip of peg board pivoted by placing a knitting needle horizontally through one of the holes and holding it in a clamp. In this way they determined the mathematical relationship involved.

The ideal in learning is achieved when children are led through a rich variety of experience while along the way the teacher is able to extract, exemplify, reinforce, clarify and relate ideas and knowledge so that the pupils are provided with education that forms a whole, although they still understand and gain from its separate parts. As far as science is concerned and possibly other subjects too, the more this ideal is pursued, the greater is the demand made upon the teacher's understanding and knowledge of the subject and its requirements, and also upon his or her professional skill and expertise. Teachers have to bring to the task the kind of professional skill, which, beginning with a thorough knowledge of the children and how they learn, leads to an understanding of the contribution that can be made to general education by a variety of experiences and by the ways in which those experiences can be both analysed and synthesised; they must also gain a knowledge of science, and an understanding of its nature and of its particular contribution to general education. It seems wholly unreasonable, not to say unrealistic, to expect all primary teachers, or even most, to be able to meet this kind of demand and any insistence on it is unlikely to result in good science. It is perfectly proper to make small beginnings, with teachers taking some of the science content they feel most confident about and, at the start, organising the children's investigation and learning in a fairly formal way. Experience brings greater confidence, and encourages expansion into a wider field; links with other subjects and activities will soon begin to suggest themselves. Chapter 2 suggests a few useful starting points.

Links with other subjects

Important relationships exist between science and other areas of curriculum. Practical enquiry by children in groups or as a class involves debate and discussion, as well as reading and writing. Science gives opportunity for the development of language based on first hand experience. Children's language is extended through use in a variety of forms aimed at particular audiences, as well as for dealing with reference and general reading texts. Often there is a demand for the application of mathematical skills such as computation and the construction and interpretation of graphs. Science may start from or lead to the study of historical events of characters. Movement and physical education can include good examples of force or friction. Transport is a common topic in primary schools and a knowledge of science would help teachers to offer children a deeper understanding of its history, its development and its use. A study of canals in Britain may lead to an investigation into the shapes of boats that travel in restricted waterways, or into the operation of locks. The question "How was the water maintained in the canals?" could give rise to some practical experiments as well as to some research in schools or local library.

The intellectual processes listed at the beginning of this chapter are not unique to science and this facilitates links across the curriculum such as those mentioned above. But there are also pitfalls. It is sometimes thought that all or most of the science experience children need can be included in or extracted from a whole range of activities which have other and different objectives. Unfortunately it is very seldom that such an approach leads to good science education. The reasons lie in fragmentation of the subject; the labelling of parts of the activity as science when they may not be scientific at all; and the use of unsuitable science topics because they seem to fit the general topic. Science can be taught and learned through more general studies and it can be splendidly done but it is far from easy and requires outstanding knowledge, expertise and insight from the teacher. Links are desirable but they should not become chains which restrict pupils' development in science.

2

Continuity and progress

Apart from English and mathematics continuity in the primary curriculum has been subject to much neglect. Continuity across phases, such as from primary to secondary education has suffered a similar fate. Science suffers at least as much as other subjects, and perhaps more than some, from discontinuity. Some scientific ideas are more complex than others, but most can be met at different levels of complexity; some rely for understanding on the grasp of other scientific facts and principles. There seems little doubt that some concepts are understandable only at certain stages of general intellectual development. For example, ideas about atoms and molecules can only be presented at the most general levels for younger children: "something which is very small" is likely to be the limit of understanding of most of them.

Science covers a vast and ever-increasing field of human activity but at the same time there are fundamental aspects that must be understood by every pupil, although not necessarily pupils at the same age, if they are to make progress. There are, in science, not only lines of development as suggested earlier but sequences to which attention must be given if worthwhile learning is to take place. On pages 14-16 some examples of these are given. Perhaps it is indicative of the lack of continuity in science in the primary curriculum to say that in most schools science is not assessed. If any difference does exist between the work done in successive years, it relies on change of topic and the general maturation of the children bringing such developments as a greater command of language and ability to write rather than on any clear idea of progression in science. It is not unusual to find the same topic covered at the same intellectual level in different years, or topics chosen without regard to each other or to their conceptual difficulty. Sometimes teachers are unaware of the work pupils have covered in the previous year or that they are likely to cover in the succeeding year. Schools often have no general scheme of work for science. A common policy on science education among schools in an area is a rarity.

It is important for the teacher to know in detail the range of work already encountered by each pupil in science, the level at which it has been tackled, and how successful he has been in mastering the ideas and knowledge involved. Every school record should contain information on these three aspects of each pupil's science education. Results of any tests given should also be included. This implies careful assessment and an informative record to be passed on — and used. Too often class records appear only once a year, when they are filled in and are then relegated to the stock cupboard. Schools often use record forms supplied by LEA. Many LEAs have gone to some lengths to produce well constructed forms for this purpose. However since such a form must apply to all schools within the area it may fall short of the requirements of a particular school. There is much to be said for adding to the LEA's record other information — about progress in science, for example — which is specific to the school's style of operation.

Transfer between schools

It has long been the custom for our educational system to contain for pupils at least one major change of school with significant changes in the curriculum pattern, modes of learning and teaching, staffing and resources. The effects of such a break upon pupils are commonly deplored, but, in the main, attempts to encourage curriculum continuity have relied on often limited information passed by record cards from school to school, sometimes, but not always, with some personal contact between members of staff. Where the latter occurs, more often than not it is general in character rather than specific to a subject such as science. Very few secondary schools, especially if their intake is drawn from a large number of primary schools, can rely on any degree of common science experience on the part of their new pupils. The inevitable response is to behave as if the pupils had received no science education before entering the school, and, unhappily, this may often be true. Detailed assessment and recording of science in primary schools can help to improve this situation. If science teachers in secondary schools know what science has been done, what concepts have been met, what knowledge gained, and what skills practised, they will find far less justification to ignore or under-value their pupil's earlier experience. However, there still remains the variation in science activities from school to school. There seems no good reason why the primary schools in a given area should not institute some simple cooperative procedures over science. One decision might be that every primary school would teach science and give a definite proportion of the timetable to it. Another might be to adopt a commonly agreed core of science topics that all would cover, whatever else might be done. Local authorities and their advisers have an important part to play in setting up arrangements to facilitate this kind of cooperation. Some authorities have already begun to attack the problem of continuity. In one case a programme has been set up for the production and testing of experimental material for use at ages 7-11. The aim is to provide a large number of basic work sheets with the associated apparatus available in boxes. The material is intended to fit into whatever system of science teaching is adopted, either as a separate part of the curriculum or as a planned part of broader work but to provide a basic degree of uniformity in the subject area covered. Another approach, used by a number of authorities with middle schools, is to set up working parties of teachers from all the schools concerned with the aim of drawing up a list of science activities and content for all to follow.

Cooperation, whether between teachers in one school or in a number of schools, is indispensable to continuity and progress. It is not difficult to arrive at a consensus on basic science education for primary schools. Little, if any, educational freedom is surrendered by doing so and the gain for both pupils and teachers is considerable.

Constructing a scheme for work

There is much that can be done to improve matters. The benefits of a well constructed scheme of work can hardly be over-emphasised. This is an important part of the school's policy for science education to which reference is made in the following chapter. Such a scheme of work should emphasise progression in concept, content and intellectual demand. It should contain not only lists of topics but advice on suitable approaches, on practical work that has been found successful, resources that are available within the school and outside it, on ways in which work on the science topics might be extended and on the pitfalls to be avoided. There should also be a clear indication of the assessments to be made of the pupil's development and the methods to be used. A scheme of work of this kind is best drawn up as a result of discussion between the head and all the teachers concerned. Regular revision is vital, as are monitoring procedures to discover how far objectives are being met and what changes may be necessary.

In considering the structure of a scheme of work there are a number of factors to be borne in mind. Young children ask many questions about their environment, and these often have to do with science or applications of science. There is much to be said for basing work upon these questions. Children are highly motivated if they are pursuing investigations that arise from their own interests, and are significant and applicable to their present lives. Furthermore, it is seldom that solutions to problems raised by children involve investigations limited only to science. An investigation that sets out to discover the preferred food of a gerbil, for example, could easily lead to geographical considerations of its natural habitat thus leading to a beneficial integration between science and other areas of the curriculum. But is is difficult to teach science this way all the time. Thirty children in the class may ask 30 different questions and wish to pursue 30 different interests, or more likely, perhaps 15 will ask questions and 15 will show no interest at any given time. Furthermore, there are dangers of lack of coherence, repetition of certain kinds of work, or mismatch between what the child would like to do and what he is capable of doing, of leaving huge gaps in the children's experience of their environment, and failing to give them basic ideas upon which to build an increasing knowledge and understanding of their biological and physical world. The latter point also has implications for the transition from the primary to the secondary phase.

A strong case can be made for deciding upon some common content and for devising a scheme of work that prescribes content, appropriate to their abilities, for children in primary schools. Indeed, this might be done for the whole period of compulsory schooling from age 5 to 16. It may be important to stress that no matter whether science arises from the children's (and the teacher's) interests or from prescribed content, the development of scientific skills and processes is all important. Whatever the science they are doing, the children should be involved in observing, investigating, experimenting and predicting; they should also be using their science in technological activities that present real-life problems to be solved and things to be designed and made. A scheme of work that specifies content and indicates some of the ways in which it might be taught could be helpful to the teacher who wishes to arrange for the children to do science — that is, to use its skills and processes. It could also be helpful to the teacher who lacks knowledge of science, is unware of what concepts are important and who lack confidence.

Care and thought are required to produce a properly constructed scheme of work. One problem is how to decide upon its content. Another is a possible lack of flexibility; a teacher concerned with keeping to the scheme may not be alert to new things that come along. It is very unlikely that at any given time the content will be satisfactorily for all the children in the class; for some it may be too difficult whereas for others it may be insufficiently advanced. This, however, is a problem that faces the teacher of a mixed ability class whatever the subject, and a good teacher will try to introduce appropriate differentiation. It is a problem that arises whether the course is structured or unstructured, though a structured scheme of work provides better for different abilities if careful thought has been given to this aspect in drawing it up. There is a place for the science that stems from the children's interest and from questions that arise locally, at home, at school or elsewhere, and for that which arises from a scheme of work devised by the school. A combination of the two may best exploit the advantages of each without incurring, to any great extent, their disadvantages; it is impossible to be precise about the balance between them. This depends upon a number of factors including the type of provision for science within the school, the nature of any agreement with neighbouring schools on a policy for science, and the skill and knowledge of the teacher concerned.

Criteria for selecting content

Apart from providing a suitable vehicle for the development of the skills and processes of science, the criteria used to select the content of the course should be specified in such a way as to encourage the involvement of children in doing science and not just reading or hearing about it. For example:

1. The content should, wherever possible, be related to the experiences of the children.
2. It should, in accordance with their stages of development, provide them with knowledge and understanding of scientific ideas to help them to understand their own physical and biological environments and to understand themselves.
3. It should, where possible, lay the foundations for a progressively deepening knowledge and understanding of scientific concepts and facts that will be useful to them as future citizens.
4. It should include examples of the application of science to real-life problems including those of technology.

3

Development of scientific ideas

Criteria as broad as those just outlined can give rise to may different statements of content, although it is likely that they will all have some common features. There is much to be said for discussions between primary schools in a given area and, on the question of continuity and the introduction of important concepts, with neighbouring secondary schools.

In considering the progression of a particular aspect of science, it is helpful to look forward to an end point. What is it that a particular pupil might be expected to know about a particular topic by the time he or she is ready to leave the school? What additional ideas might be met, first, by the brighter and, second, by the brightest pupil? It is important to remember that scientific skills have to be practised and this must take account of children's development. Very young children looking at insects are unlikely to notice the detailed structure that we would expect older and more experienced children to observe, and their drawings might not include jointed legs or a segmented body. The patterns recognised by older children are more complex and at a higher level, so that while six year olds will understand that a short pendulum swings faster than a long one, we should expect ten-year-old children to realise that the relationship between time of swing and length of string means that a pendulum can be used as a timing device. Part of the role of the teacher is to ensure that there is progression in the development of scientific skills and thought processes as the children make their way through the school.

It is not difficult to list, in order, statements about a particular topic and then to rearrange them in a suitable progression. Two examples are given at the end of this chapter: 'Living things', set out in the form of statements, the other 'Energy', indicating a progression of ideas.

Different content is not of itself sufficient to distinguish work appropriate for different years. If science is taught in conjunction with other subjects, the choice of material must be carefully made so that, while it contributes to the broader area of work, it also fits into a continuum of scientific ideas and levels of complexity. The range of ability within the class also requires attention. It is commonly assumed in primary science that all pupils can learn from pursuing the same topic. This may be so if there is an appropriate range of ideas and levels contained within it, and if the various pupils are carefully guided towards appropriate experiences. However, these conditions are not always met and continuity for some pupils may be seriously upset if they are presented with work that lies beyond their understanding. Sometimes it will be right for different groups of pupils to undertake different practical work with different ends in mind. Besides, the range of ability in science is not necessarily the same as that in other subjects such as English. It would be unlikely for a child's reading age to be the same as his 'science age', even if such a thing could be measured. Good science teaching gives opportunities to use basic skills of literacy and numeracy effectively and often breaks through imagined ceilings of attainment.

Examples

Living things

In this example 16 statements are made about living things. They are not in any particular order nor are they necessarily the only statements that might be made for the purpose of primary schools. Obviously the same ideas might have been stated differently. The object is simply to assemble a list of knowledge and ideas and then to look at it in the light of the different age groups and ability levels within the primary schools.

1. Living things depend one each other in various ways.
2. Mammals are warm blooded.
3. There are certain requirements of food, air and water that are different for different kinds of living things.
4. Plants take up substances from both the air and the soil and respond to light.
5. Many living things have adapted their life style to seasonal changes.
6. Man makes use of animals and plants to provide both food and other raw materials.
7. Water is essential to life. It makes up a large proportion of living things.
8. The life cycle of any living thing is repeated in each generation.
9. Young living things need additional care and protection if they are to grow into healthy adults.
10. Some animals eat plants and some eat other animals but all animals ultimately depend on green plants for food.
11. Living things are usually well suited in form and function to the environment in which they are found.
12. There are many different plants and animals which between them show a variety of ways of carrying out life processes.
13. Green plants can make food, animals cannot.
14. All living things produce waste materials in carrying out life processes.
15. Most living things take in oxygen from the air or from the water in which they live.
16. Living things produce offspring of the same 'species' as themselves.

Looking at the list it is possible to associate particular statements with particular years in the primary phase (5-11) and particular levels of activity. Clearly some statements can be approached at a variety of levels and will be returned to in later years but it is important that the latter treatments embody greater complexity of ideas and make greater demand on thinking and grasp of concepts and not merely further 'drill' on the same material.

Year	**Statements**		**Activity**
1 (reception)	2,5,6,9		Children may have opportunities to observe and handle classroom pets. Their attention will be drawn to the characteristics of mammals. Most infant classes draw attention to seasonal changes [seed time and harvest in particular] and where food and clothes come from. Farming is another idea commonly mentioned.
2	3,1,9,12	Infant	Pupils can discover that seeds will grow if they are provided with water. Other things are also needed for complete development of the plant. Baby animals can be observed or shown on film or video tape and their needs discussed. At the same time interdependence is illustrated. They can begin to look at the variety of living things.
3	7,8,10,16		The abundance of water creatures and the need of both plants and animals for water are easy to illustrate. Given a variety of experience of living things, statement 8 can be grasped almost without emphasis. Food needs of various animals, including man, illustrate 10. Experience of living things and their offspring begins the understanding of 16.
4	5,12,14	Lower Junior	More systematic ideas of leaf fall, hibernation, and migration can be introduced. Ideas on the variety of plants and animals and their styles can be developed. The cycle of life processes can be made more specific. [At the same time any of statements 1,2,3,6,7,8,9,10 may well be touched on again].
5	3,15		It is possible now to look more closely at the different needs of living things, including oxygen as one essential element.

Year	Statements		Activity
6	4,5,8	Upper Junior	More specific experiments carried out with plants to illustrate statement 4. The extent of adaptation to seasonal changes can be developed.
7	11,13, 15,16		The ideas of adaptation to environment can be made more specific. Experiments can illustrate the food production of plants, and the production and use of oxygen. The idea of species can be introduced. Reproduction and heredity are also possible topics.

In many of the later years, work on or at least reference to, statements that have been met before will be included. The groupings given are no more than a skeletal outline of a sequence of work and are intended to do no more than illustrate the principle. At the same time an 11 year old boy who had grasped the essential features of these 16 statements, who had been presented with the evidence underlying them, and had carried out observations and experiments himself to illustrate them, would have a useful knowledge of living things.

Energy

This example looks briefly at the development of one topic, energy, across the age of compulsory education (5-16). During their early years children can learn the word 'energy' and begin to understand that energy is something real; and that to be able to continue using energy, they (and other animals) need food and machines need fuel. Their observations and experiments may indicate that plants also need food, as well as energy from the sun, if they are to grow and provide food for animals and for man.

As the children get older, more and more of them may come to understand that heat, produced by fuels in other ways, is a form of energy and that it is often wasted. The need to conserve expensive and diminishing sources of fuels can lead to investigations into ways of reducing this loss, including experiments with different types of insulators. Work with plants can involve investigation of the best conditions for their growth, and possibly of the materials in them. By the age of 12, able children may have acquired a clear understanding of the fact that energy can exist in different forms and that these can change from one to another. The less able, however, may have to wait longer before they can appreciate these transformations.

Towards the age of 16, pupils may have had sufficient experience for most of them to know that the useful energy output from any machine is always less than the input, and to have some understanding of the principle of the conservation of energy, or the first law of thermodynamics. Their investigation may have helped them to formulate concepts on energy changes occuring in chemical reactions — on energy expenditure needed to extract metals from their ores, for example — on energy changes occurring in plants during photosynthesis, and so on. Able pupils may have acquired a much deeper understanding, and an appreciation of, the joule as the fundamental unit of energy, and of its uses in calculations involving different forms of energy such as potential and kinetic energy, heat and electrical energy, and that these have biological, chemical and physical applications; some may even have a simple idea of the second law of thermodynamics. All pupils may have gained a broad knowledge of social issues concerned with the need to conserve fossil fuels and to develop other sources of energy.

4 Children's work in science

What kind of work does go on in schools and how some teachers make a start on scientific work in their classroom is illustrated in the following examples and some indication given of the features which characterised the work.

1. *A class of first year junior children in an inner area of a large city*

The conditions in which the work went on were fairly typical of the area. The school, built more than a century ago, was surrounded by old property, some of which had become derelict since the closure of nearby docks and the consequent run-down of associated trades and industries. The teacher had trained for three years with history as her main area of study and had taught for four years. She had been on the staff of this particular school for four terms.

Scientific investigation first begun when she took her class to the swimming baths and they became very interested in the echoing sounds. When she was asked by the head if she would try to develop some scientific activity as well as the language work she had already planned, she agreed on condition that she would be able to get help from someone somewhere if she needed it. Thus reassured she planned her work.

She begun by making a tape recording of the noise in the baths and used it as the basis for class discussion. The children wondered why voices sounded so loud, and there was much talk about echoes and about sound 'bouncing' off the walls and the roof.

At this point the teacher took a number of significant actions. She collected some of the Schools Council Science 5-13 booklets, the Nuffield Junior Science Teachers' Guides, and the Collins Junior Resource Book so that she could both extend her own background knowledge of the subject and alert herself to the teaching possibilities now open to her. She also joined a local 5-13 follow-up group which met informally in the area once or twice each term, and there she discussed with other teachers the work she hoped to develop. She next visited the teachers' centre and talked to the advisory teacher for science based there.

He suggested a number of experiments she could try out and offered to lend her the necessary equipment. From now on she had a number of lines of enquiry to follow.

During the next visit to the baths the children tried to find out if sounds would travel through water. A girl stood in the bath, plunged the school handbell into the wter and rang it. The children at the other end of the bath dipped their heads under the water and were able to hear the bell ringing. Back in school they held a watch against their heads behind their ears and heard it ticking; they put the watch on one end of a desk top and listened to its ticks by putting their ears against the other end; one girl suggested that they might fill a balloon with water, hold it against their ears and place a watch against the other side — they should be able to hear the sound through the water. They also made tin can and string 'telephones'.

They 'bounced' sound off a wall by directing the sound of a watch ticking along a cardboard tube and listening to it through another tube.

They made a tape recording of noises in the street and talked about the different sounds they could hear.

The teacher asked them why they needed *TWO* ears. To find out, she took them into the hall and arranged them in a large circle with one child in the centre. She blindfolded this child and asked her to point in the direction of the various children in the circle who were asked to make noises. The child then had to repeat this with one ear blocked with cotton wool. She found that now it was not nearly so easy to tell. Next the pupils tried to say where the sounds were coming from as they stood beside a large cupboard in the hall. Finally they measured how far away from a clock they could stand and still hear it ticking. They drew a graph to illustrate this.

They were given two minutes to listen in silence to sounds in the classroom. They then repeated the experience in the school hall. The discussion which followed began to help them to realise that their brains enable them to shut out extraneous sounds and concentrate on the few selected ones they wish to hear.

One boy, whose father was a musician, brought instruments to school and the class examined the different ways in which these instruments could be used to make sounds, blowing, plucking, bowing, striking — all of which led the teacher to talk about vibrations. She and the children followed this up with a series of demonstrations such as watching rice bounce on a drum skin when the drum was played and a bit of paper flying off a guitar string when the string was plucked, feeling the vibration of a paper and comb instrument, watching a vibrating tuning fork make ping pong balls fly or cause a ripple on a water surface and feeling the fork vibrate against their lips and cheeks. The children also played tunes on bottles with various quantities of water in them, drawing a chart relating the pitch of the notes produced to the amount of water in the bottle. They made a similar one by drawing round the metal plate from the class xylophone and sticking the strips of coloured paper on to a card.

It was at this stage of the work that the teacher extended the range of resources she was drawing upon. She arranged to visit the museum in the city and the school service curator showed the children a collection of old musical items. They were very excited to see old musical boxes, phonographs, and a large pipe organ, and to play on a harpsichord and a spinnet. All of these experiences gave rise to a great deal of oral work back in the classroom.

She also visited a local SATRO* resource centre from which she borrowed tuning folks and a frame from which hung metal tubes of different lengths. These were to be played like tubular bells but they were slightly inaccurate and had to be tuned by putting small pieces of plasticine on them. The warden of the resource centre also made her an 'elephant scarer' and suggested how she might use it as the start of scientific enquiries.

A bonus from these activities was that she learned that sometimes her pupils did not understand words and expressions that she had thought they did. Similarly she was surprised to discover that some children did not know how to measure or to do some simple pieces of computation even though they had apparently understood them at an earlier stage. She was able to take steps to remedy this situation.

With the confidence gained from this work she decided to continue and with her class she is studying *Holes, Gaps, and Cavities* (Schools Council Science 5-13). So far the activities have included a walk along the street to look at chimneys and under manhole covers — to wonder why the drain cover has bars across it instead of just a hole — and hence to test the effect of a sieve. They have included an experiment with cake candles under chimneys of different lengths made from cardboard tubes. A dentist visited the school and brought in some teeth with cavities. The class borrowed some skulls from the local museum, and made a trip through a tunnel. Following up these activities they made a study of the strengths of various structures.

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*Science and Technology Regional Organisation. There are 24 of these throughout the country and they are all anxious to help the development of any scientific or technological work in any school.

2. *Another class of first-year juniors*

The teacher of this class had been trained to teach infants and had been doing so until the year before. When the present headmistress arrived at the school she had emphasised to her staff how important it is for primary school children to have experience of scientific activities; the teacher met the demand through practical work in mathematics and by examining the day-to-day problems that rose regularly as the children explored the environment and materials in the classroom.

When she was asked to teach the first year junior children, although she felt far less sure of herself with this older age group, the teacher agreed to try to develop work in science, knowing that she could ask for help from the headmistress and take part in discussion with other teachers. The headmistress suggested the topic *'Science from Toys'* and provided 5-13 support books. She also produced a helpful scheme of work.

The teacher's first task was to identify a problem she felt able to tackle and was at an appropriate level of difficulty for the children. She settled for running toy cars down slopes. She realised that for the experiment to be valid she must change only one variable at a time and so she decided to investigate the effect of varying the slope on the distance travelled by the car after it ran off the bottom of the slope. The children measured the distances with strips of coloured adhesive paper which they then cut off and stuck on to a wall chart. They repeated the experiment with three other toy cars and established that there was a common pattern to the behaviour of cars.

Next they added weights to the same car and ran it down the same slope inclined at a fixed angle to see what effect the weight of the car might have on the distance it travelled. They then ran the same car down the same slope but covered with different surfaces. Finally, they made a car from a construction set, ran it always from the same spot on the same slope but fitted a series of wheels of different sizes to the car. In all these cases, having established the pattern, they were able to predict what might happen in a new situation and put their predictions to the test.

The teacher then turned her attention to magnetic toys, again using books as a source of ideas. The class begun by suspending magnets from pieces of thread, trying to find the northern direction from the way the magnets pointed when they came to rest. They then investigated the powers of attraction and repulsion between magnets. Next they sorted common objects and materials into those that were magnetic and those that were not.

All this work was heavily based on what the teacher recalled from her own school days and on what simple science experiments were to be found in books in the class library. But now, having gained confidence, she began to discuss with the class ways in which magnets might be put to practical use. They built a train with carriages made out of plastic boxes which they attached together with magnets.

This was as far as she could securely go with magnets and she looked around for a new topic. Since the class was studying time in mathematics, and the children were clearly having some difficulty with understanding the passage of time, she decided to investigate candle clocks. This was done very simply by measuring the lengths of candles before they were lit and at intervals as they burned down. The results were recorded in the form of candle cut out of adhesive paper and stuck on to a chart, which also recorded length and time of burning. Later, she tried to introduce the idea of a linear scale to represent the time the candle had burned but found that this concept was too difficult for this group of children.

It was at this point that a city-wide competition was started and although this class did not submit entries, they did begin to look at the effects of currents of air on various objects. For instance they made paper windmills. They also made balsa boats on to which they could fit paper sails of similar shapes but different sizes so that they could investigate the effect of sail size on speed. The wind was supplied at first by children blowing through drinking straws but this they felt was not a very reliable wind source, so they tried to improve it by squeezing a plastic bottle. They measured the effectiveness of the sails by timing the boat over a set distance.

3. *Third year juniors*

This teacher, in her third year of teaching, did biology at school, and had found her science curriculum course in college unhelpful. As far as she could see it had no obvious relevance to the work she was required to do when she started teaching. However, she was fortunate to have a period of practice in a school that was interested in science and whose headmaster was very supportive. Because the school had a science programme set out in its scheme of work she found herself having to face up to the fact that she would have to teach science using a selection of the 5-13 books as a source of ideas and suggestions. Because she felt that she had achieved a reasonable degree of success, she was prepared to continue the working during the two terms of her first appointment as a temporary supply teacher in charge of a remedial class. Two years ago she took up her present post.

The headmistress of the school had been anxious to develop science in the curriculum but because of staff reluctance had taught most of the classes herself. She offered to continue doing so but the teacher preferred to do the work herself. She found the scheme prepared by the headmistress very useful because it not only set out the general aims and objectives of the work but also gave examples of what might be appropriate topics for the various age and ability groups of children. The teacher chose to do work on colour.

Halfway through the year, however, a new factor was introduced. The Authority's teacher adviser for science initiated a city-wide programme on energy which was to culminate in an exhibition in the teachers' centre. This teacher took up the challenge and chose Energy as a theme, once again turning for initial impetus to the 5-13 books and to the school and class libraries for science books.

The class began by looking at compressed air as a source of energy. They collected a number of plastic bottles of different shapes and sizes, plugged the necks with corks or plasticine and pressed or jumped on them. The energy put into the air when the bottle was squeezed now appeared as energy of motion as the cork or plasticine was propelled through the air. The children tried to blow the plugs as far as possible by varying the amount of energy they put into the bottle.

Next they used balloons of different sizes, blowing them up as fully as possible, releasing them, and trying to measure the distances they flew. The flight paths were, of course, very erratic and more control was achieved by hanging the balloons from nylon fishing line stretched across the classroom.

They then turned their attention to boats floated in water in a length of plastic guttering purchased at a discount from the local SATRO resource centre. They decided to propel the boat by means of a rubber band attached to a home-made balsa wood propellor and found there was a relationship between the distance travelled and the number of twists of the rubber band.

Finally, some children brought to school a cutting from the children's page of a local newspaper which gave instructions on how to make a fan from a squeegee bottle, a plastic propellor and a rubber band fixed to a piece of wire. The class followed the instructions and made fans.

At the beginning of the second year the headmistress decided that the school should investigate *Science from Toys*' as a theme. The class began to study toys that would fly, their first venture being a hot air balloon. They made a paper model of the Montgolfier brothers' balloon, painted it to look like the picture in the book they had taken the story from and flew it in the school hall, using candles as a source of hot air.

The children next turned their attention to model aeroplanes made to their own designs and constructed at first from paper but later from balsa wood. They asessed the quality of the models by the stability and distances flown. They enjoyed this and achieved considerable success. One group tried modifying the balance by adding plasticine weights to the noses and tails of the aircraft. The next area of enquiry was that of magnetic toys, and this in turn led to a more general study of the properties of magnets. They made, for example, a football game and a collection of dancing dolls operated by moving magnets under a board, a magnetic fishing game and, after one boy had discovered a reference to them in a book, magnetic maps using iron filings on paper placed over magnets. Finally they took a collection of common materials and divided them into magnetic and non-magnetic, recognising in the end that the magnetic ones were all made of either iron or steel.

At this point, at the beginning of the second term, the teacher adviser invited the city's primary schools to enter a competition in which they were to make machines to travel on either land or water, the only proviso being that they should carry their own power supply. The class responded by making machines driven either by rubber bands, by balloons or by small electric motors. They included as an extra a fairground roundabout driven by a rubber band. Three of the boys were among the winners of the competition.

Some important points

i. The teachers, whose work is described in this chapter had been given little appropriate working experience of science during their own school days but each of them was knowledgeable about young children and about the kind of experiences that were suitable for their particular classes.

ii. Each was impressed by the headmistress's insistence that science was important in the education of primary age children and they were reassured by the existence of a scheme of work that laid down general guidelines and offered practical suggestions.

iii. Each was prepared to look for suggestions and help in a selection of books, some intended for teachers, others for children.

iv. Each felt reassured by the knowledge that the headmistress was prepared to discuss their plans with them and to give help in the classroom if required. Indeed, she helped one of them to organise practical group work until the teacher felt that she could do it on her own.

vi. All the teachers concerned have been encouraged by the ingenuity of the children and the quality of ideas and suggestions they have provided. They are also impressed by the extent to which discussion either as a class or in small groups develops children's spoken language and by the way in which children's interest in practical activities stimulates them to use books, either as general reading or as reference works.

vii. Science advisers gave valuable help by organising courses, joint activities, by providing books and equipment on loan, and, not least, by simply being available.

viii. The opportunity to meet and share problems with a group of interested teachers was a considerable help to the teacher in the first school.

ix. There is valuable help to be obtained from SATROs and from outside agencies such as museums and zoos.

Examples of help and support

i. A whole staff might decide to develop a science policy and meet regularly to discuss its operation. The science adviser in one authority has worked in this way with a group of schools. He and a college tutor (who has also evaluated the scheme) have worked in the schools, arranged meetings, prepared handout materials and encouraged the production of 'swap packs'. These consist of notes made by the teachers on the work the class has done, explaining the planning, the collection of resources, and the snags and difficulties encountered. Teachers are now able to exchange these and so develop work based on the experience of others.

The teacher adviser also organises activities designed to stimulate science activities in schools. For example, he encouraged schools to do work on the same topic and, after two terms, no fewer than 65 infant, junior and primary schools contributed to a display of work in the teacher's centre. This was visited not only by teachers but also by many classes of children; it sometimes acted as a starting point for further work. The teacher adviser initiated a competition in which children are asked to develop an efficient machine that will travel either overland or on water. Most authorities do not have teacher advisers but a number of other supporting agencies are usually available. Some teachers, for example, are in touch with tutors from nearby colleges.

ii. In one authority, nine tutors from a college science department are committed to spending half a day each week in nominated primary schools so that they can advise and help in whatever ways are thought to be most appropriate — sometimes leading discussions or, perhaps, teaching alongside the class teacher. Whatever method is employed, there is no doubt that children, teacher and tutor all benefit. One tutor runs a 'clinic' first thing in the morning and spends the rest of the day working in selected classes. Some schools look for support from local secondary school science teachers, and there are a few examples of secondary schools arranging one day courses at the request of primary schools or helping in other ways — such as lending equipment or discussing the science content of what is to be taught while the class teacher decides on what is actually appropriate for the children.

iii. In one primary school a class of children and their teacher spent an afternoon in a nearby secondary school with the primary and secondary teachers sharing the teaching in the laboratory and planning the follow up work to be done in the primary school. A few primary schools have a qualified science teacher on the staff and the other teachers call on him or her for help and advice.

5 Organisation and staffing

The evidence from the visits to schools by HM Inspectors indicates that in general science in primary schools falls far short of the level of effectiveness which is often claimed for it. The HMI report Primary Education in England 1979 found that few primary schools visited had effective programmes for the teaching of science. More recently the APU reports have shown that although few schools admitted to no science, few gave more than five per cent of the time to it. In junior and junior and infant schools, among the goals for science only 29% listed understanding of basic science concepts, only 8% familiarity with the correct use of simple science equipment, only 9% the ability to plan experiments.

Whether this situation stems only from a need for in-service training and from lack of provision of adequate resources or whether it is a problem which concerns just as much the patterns of organisation and staffing of primary schools is a question which requires investigation. Another factor is the concept of primary education held by parents and other members of the public which has consistently emphasised language and mathematics — sometimes in the most limited sense, reading, writing and arithmetic. This has inevitably influenced the perception of teachers and heads.

If the whole curriculum is to be well taught, heavy demands have to be made upon individual class teachers, who are expected to tackle a variety of subjects, in some of which they may have a very limited academic background. Such demands inevitably lead to the situation in which mathematics and English overshadow the curriculum and all other subjects trail a long way behind except where the enthusiast raises their stature.

More particularly we might ask whether it is reasonable to expect all or even most teachers to teach science without support of a kind and quantity that is wholly lacking at the present time. Many of the teachers who, to their credit, are willing to attempt the teaching of the subject nevertheless fail to understand its nature and requirements. It may be that this lack of background explains why two fully fledged curriculum development projects (Nuffield Junior Science and Schools Council Science 5-13) with their attendant in-service training programmes have failed to engender a large scale development of science in primary schools, despite much dedicated effort on the part of LEAs, advisers and teachers. In these circumstances, it seems necessary to reconsider the staffing patterns in primary schools. Clearly the more teachers the head has the more flexible he can be in utilising their available knowledge, interests and skills in various areas of the curriculum for the benefit of the school as a whole. There may be good reasons why particular primary schools should be of a certain size — because they are in rural areas for example, but if all other things are equal it is likely to be easier to educate effectively across a broad curriculum in a larger school than in a smaller one. Heads have always sought expertise in some subjects when appointing staff; music is one example. It may now be time to look for a spread of subject background among the teachers in a school to ensure that all parts of the curriculum are adequately represented. This implies that future appointments would be made with the balance of subject expertise in mind so that science, say, is represented by a teacher who has made a main study of the subject. Most teachers in primary schools would regard themselves as more expert in one or two subjects than in others, and it should be possible for a head to capitalise on these specialisms. A balance among staff cannot be secured overnight but a clear policy would go most, if not all, of the way towards it. Small schools have special needs in staffing and attention must be given to ways of meeting them, for example by greater use of peripatetic teachers. All schools would benefit by a well constructed programme of in-service training.

This might take a variety of forms but certainly should involve local advisers and others outside the school.

But even given the presence of some competence in the subject among the staff it is unlikely that science can take its place in the curriculum without a new status being accorded to it, or without a different concept of the structure of the primary curriculum. Sometimes it is thought to be adequately included in other subject areas (environmental studies for example) but is is very seldom that this idea bears closer examination in the light of the essential nature of science and science education. Yet the subject has much to offer to general educational development in the context of the kind of broad curriculum which receives favourable mention in the HMI survey previously mentioned. Its findings, that children were rarely presented with a writing task involving a coherent argument, asked to draw conclusions or make judgements underlines the potential value of science in primary schools. The importance of a subject in the eyes of the head and staff is closely related to the time given to it. Science need not necessarily appear as such on the timetable with a specific time allocated to it, although this may be appropriate for some schools. There may be a number of subject areas in which useful science can occur. However heads and teachers should, in general, be aware of how much attention is being given to science, when it is being taught, what skills and knowledge are being developed, and at what level.

For effective learning at the primary stage children need experiences that lead their thinking from the concrete and particular towards more generalised knowledge and concepts through steps appropriate to their understanding. This is especially so in science. They need to be able to test ideas through suitable practical work, to be guided along productive pathways and steered away from unproductive ones. It follows that the teacher of science is better placed to help his pupils if he or she has a thorough understanding of the nature of scientific activity and a broad knowledge of the subject. In this way work at a deeper level can be offered, and the superficial 'look and record' pattern often seen can be avoided. It is important for teachers to recognise the difference and to accommodate their work to fit the agreed school pattern for science. Some teachers are at their best when working with a whole class attacking one problem. Others do their most successful work when children operate in small groups. Probably it is best to vary the style to meet the demands of the occasion, with individual work, class teaching, group work or demonstration each playing a part. One service that an expert science teacher can perform for his colleagues is to show how a class of pupils doing science can be organised, either within the classroom or outside it. Groups of pupils carrying out the experiments of the same or of different kinds present problems to many teachers, especially if different groups need to be in different places. Yet such organisation is perfectly possible given careful planning, careful preparation of the pupils and sufficient materials and apparatus for them to work with.

For active science a fairly wide variety of apparatus and materials is necessary. Not all of it need be expensive and some can be virtually without cost but there are times when some fairly expensive items are necessary and should be available in sufficient quantity if the task is to be well done. Magnifying glasses and microscopes, measuring instruments of various kinds, including clocks and balances, accurate weights in sufficient range and number and a suitable range of containers in glass or other materials — all these are obvious examples. (A longer list of suggested materials is given in appendix 2). It follows that although good science can be carried out with simple materials and any school can certainly make a start, reasonable allocation of funds from capitation is needed if science is to develop well. Some support may be necessary from LEAs for the more sophisticated equipment.

If there is sufficient expertise among the staff, adequate time, subject status and money, the next requirement is a system that allows science to flourish by supplying the help and support necessary to the teachers and the necessary monitoring and control. In this the position of the teacher with special responsibility for science is crucial. Such a teacher needs not only to be knowledgeable in the field but also to be an effective planner and leader. Some members of staff find real difficulty in the latter requirement, both those who hold posts of responsibility and others. In primary schools the idea of a teacher's individual responsibility for a class has long been held in high regard and it is not easy for one teacher to accept the idea of supervising and leading other teachers — some of whom may have other senior responsibilities — or for those other colleagues to realise that the supervision and leadership are part of the support they need. It is not sufficient for the designated leader to teach science well to his or her class, or to a few classes on a specialist basis. Influence is necessary throughout the school, from the preparation of schemes of work to knowing the difficulties experienced by the non-specialist in the classroom. What proportion of the teachers will teach science will depend on the pattern of staffing. A school may have several teachers who have some background in science or perhaps only one. A specialist system for science may not be appropriate but it seems reasonable to assume that there will be some teachers who will not wish, or who feel themselves unsuited, to teach the subject. The advantage of placing science in the hands of a relatively small number should be looked at. Certainly this would reduce in the short term the problems of in-service training and support from the advisory service.

All such changes depend ultimately on the beliefs and attitudes of the head of the school and on the willingness to review the pattern of curriculum and organisation in the school. The fate of science education at primary level will depend on the leadership of heads. The support of the LEA will be needed in many ways if the decisions he or she takes with staff are to come to fruition.

6

The role of the head

If a head wishes to develop science in the school the first requirement is for all the teachers to be brought together for discussion during which the head's views are clearly outlined. It is important for teachers to be aware that the head values science highly, both as an activity in its own right and as a major contribution to many other parts of the curriculum, including such crucial areas as language development and mathematics.

The policy would need to be formulated in such a way as to enlist the teachers' help in its creation, so that they will have a shared responsibility in carrying it out and feel that they have both responsibilities and opportunities for building up their own competence in the teaching of science. Help may be forthcoming from a number of sources, including their own colleagues, but teachers should realise that the initiative for developing science is as much their own professional responsibility as it is that of the head or, where they exist, that of teachers with designated responsibility for science in their school. If, as suggested, shaping a policy for science were to become a shared task, it follows that a wider understanding of the teaching requirements to implement it would emerge among staff. Any policy statement that was agreed would be subject to continuous evaluation as ideas were tested in practice and resources were established. The process would identify the levels of expertise within the school and so indicate to the head where support was needed and what form it should take.

The amount of time to be given to the teaching of science is a basic consideration which the head will need to determine. Whether science is taught as a subject in its own right or forms part of a wider curricular area — environmental studies or topic work, for example — agreement will need to be reached on the time to be allocated to the science component of the curriculum. It may be necessary to review existing materials such as books, offering guidance to teachers as well as a balanced collection for children, aids to magnification, heating and measuring equipment, and expendable materials for practical investigations. Science involves practical activity and much work will involve investigations at first hand. It may be possible to improve facilities by making more effective use of space. Space to leave work for a reasonable period of time is needed; so are sufficient display surfaces; so is room to store equipment properly. It may be useful to review the ways in which information can be presented. Given that books — both reference and wider reading books on science topics — are in adequate supply, films, tapes, slides and teacher-produced materials are also needed. Teachers should know what audio-visual equipment there is in the school, where to find it and how to use it.

But the most important element is people and having involved his staff in formulating a policy the head will be anxious to provide them with the fullest professional support in carrying it out. One way to do this is through the use of designated teachers as 'competence models' in science teaching, showing how the work can be organised and sustained; as coordinators of resource materials; and as consultants on the understanding of content, ideas and skills in science. Another way, with the cooperation of the LEA and/or other agencies, is through in-service training. Successful in-service training seldom results from a blanket coverage. There will be different objectives for different teachers. Some may need help with their own knowledge and understanding of science content; some with their perception of science as an activity and mode of thought; some with the professional aspects of organising the pupils' work in science and enabling them to learn effectively; and others with the task of professional leadership and supervision. Perhaps for all there should be some attention given to the assessment of progress in science.

A pattern that has been used successfully is for an in-service course to be arranged in such a way as to focus upon the specific needs of individual schools. In one area, three neighbouring primary schools with similar needs arranged a six session workshop at fortnightly intervals throughout a term. The science department of a local college of education provided tuition and practical facilities so that teachers could acquire ideas and to make resource material, each teacher working with his own group of children in mind. The course tutors visited the schools to discuss the practicality of schemes and to help review the work in action. Teachers were encouraged to look at each other's work and to discuss ways of organising science activities.

The experiences mentioned by these teachers as being of most value were:

a. the chance to work together as a school staff on an in-service course lasting for a term;

b. the opportunity for them and their children to have a trial run of the necessary ideas and materials, knowing that the results could be discussed during the next session of the course;

c. visits to other schools, with the same background of a shared in-service course, with a clear purpose to the visit and a productive use of time ie visits could be made when work of particular interest was happening;

d. more discussion with colleagues and greater opportunities to see them at work in the same school;

e. a course designed to satisfy the needs of individual teachers since the tutors visited the schools and could arrange sessions to service the work seen;

f. the immediate relevance of the course to the classroom. This increased motivation and helped to establish continuity in the work, something that many teachers had found difficulty in achieving up to that time.

The local teachers' centre in another area offered similar opportunities to individual schools. Elsewhere a college lecturer ran a four session course at weekly intervals in a large infant school and the neighbouring junior school, with all the teachers attending for 1½ hour sessions immediately after school, the tutor also made visits to the classes during the course of the work to act as a consultant on the areas of science being studied and on the resources required to sustain investigations.

Clearly, the variations on such a pattern are many. For the head and teachers, the major value lies in the shared experience of developing a policy for science for the whole school in step with the growth of confidence and expertise to carry it forward.

Unfortunately, it is not uncommon for schools to start a programme for science only to find that it cannot be sustained or that the work tails off to become spasmodic, uncoordinated activity.

Some schools may not be in a position to make such close and continuing contacts with an in-service training institution as those already described. Heads often find distance and time to be insurmountable obstacles in getting much needed help in science for their schools. Other patterns have to be adopted, although the objective of involving the whole teaching staff may remain the same. In the absence of human resources, published materials might take on more importance in helping teachers to initiate and develop work. There are numerous national projects, published schemes, and TV and radio sources that may be used to stimulate work in science. Few, if any, schools are so ill-placed or isolated that they are unable to benefit from these materials, and there is ample evidence that many schools do make effective use of them.

Comparisons with other areas of the curriculum may be helpful in considering requirements for the successful teaching of science. It is clearly undesirable for a head to leave to chance the development of an area of the curriculum such as, say, mathematics. Most class teachers in primary schools are usually expected to teach mathematics. It is common for progression and continuity throughout the school to be achieved, in part at least, through the adoption of a published scheme or planned combination of published and school-made materials.

Opportunities for problem-solving and using mathematical ideas are often to be found in other areas of the curriculum. In some schools, designated teachers with responsibility for mathematics teach for some part of their time as specialists in classes other than their own. Resources are built up to support the subject and records of children's progress are commonly kept. It is reasonable to suggest that some of these techniques for developing a subject like mathematics should also be considered in the teaching of science. Most teachers recognise the importance of mathematics and teach the subject as best they can. Although many would admit to a lack of specialist knowledge, they have developed a 'working' knowledge that is strengthened by various resources.

Even those teachers lacking expertise in mathematics usually agree that their working knowledge of the subject stems from the fact that they have spent a substantial amount of time, in the course of their own education, learning to become numerate and familiar with some basic mathematical ideas whereas they have spent far less time on science. No similar working knowledge of science can be assumed. Indeed, a teacher's previous education may not even have included an introduction to basic scientific ideas. It follows that, if mathematics in schools needs to be well resourced and supported from a background of relative professional strength, science, having less traditional experience to rely upon, will need far greater provision and more supportive treatment, and unless science is accorded similar importance, it is unlikely that the climate can be created for its effective development in the school as a whole.

Various sources have been mentioned from which help may be forthcoming and the head may wish to enlist any or possibly all of these. He will also be wise to gain the support of the science adviser. Indeed most science advisers are anxious to be involved in any science development in primary schools and often able to give considerable help in a variety of ways.

APPENDIX 1

Implications and Recommendations for Schools and Local Education Authorities

A. For schools

1. The headteacher and the staff need to consider:
    - a. The nature of science and its requirements for effective learning;
    - b. the pattern of the whole curriculum and what should be the role and place of science within it;
    - c. the organisation of the school, particularly in relation to the expertise of individual teachers and to the role of the science consultant or designated science teacher;
    - d. how to evaluate from time to time the effect and effectiveness of science in the curriculum;
    - e. how to ensure steady progression in the skills and processes of science;
    - f. the constraints imposed by the building and physical resources within the school;
    - g. what human and physical resources are available outside the school and how best to utilise them.

2. The teachers need to consider:
    - a. what processes and what content is appropriate for them to teach and for the children to learn, and the balance content and process;
    - b. how to ensure a sensible progression in any area of content;
    - c. how best to organise their classrooms;
    - d. their own roles, their attitudes and knowledge;
    - e. their own in-service needs and the amount of help and support availabl

B. For the LEA

1. The local authority needs:
    - a. to develop and state a policy for science in primary schools — a policy th has sufficient flexibility to allow schools to implement it in their own way
    - b. to plan a strategy for implementing that policy in schools;
    - c. to consider how to evaluate the success and effects of the policy;
    - d. to consider how best to make use of college tutors and secondary school science teachers.

2. In considering its strategy the local authority should consider:
    - a. whether to apply it in the first instance to all schools or to concentrate on a few;
    - b. how to enable primary advisers and science advisers to give mutual help and support;
    - c. the possible function of longer courses;
    - d. how to ensure that all schools are fully informed on sources of help and advice and how best to make use of them.

APPENDIX 2

Resources

Main services

Ideally, in every classroom there should be a sink with hot and cold water. If this is not provided and the children have to carry water from taps in the cloakroom it is useful to keep a supply of water in the classroom. The most satisfactory containers for this purpose are the plastic water carriers used by campers, or plastic jerrycans, depending on the strength of the children who have to use them.

Apparatus and materials

The apparatus and materials which children use in the course of their investigations fall into four broad categories:

1. scientific apparatus and equipment.
2. tools and materials and constructing things.
3. materials for recording and communicating.
4. books and other reference material.

If these are readily available, the children can be encouraged to seek what they require for themselves, and return it to its place after use.

1. Scientific apparatus and equipment

The following lists indicate the kind of equipment which teachers have found most useful.

a. Tools of investigation

Magnifiers — hand lenses, 3D viewers, microscope
Stopclock or stopwatch
Thermometers — 10-110c clinical, maximum and minimum
Measuring tapes long and short plastic clothes line marked in metres and feet
Measuring jugs and measuring cylinders, eg 1½ pt showing fluid oz and cc
Measuring spoons — kitchen types, plastic
Weights — for kitchen scales, hanging weights, washers, etc
Spring balances — 0-100g × 1g and 0-4lb × 1oz
Kitchen scales — balance type
Letter balance
Trundle wheel
Plastic funnels — various sizes
Assorted corks
Set of cork borers
Glass tubing, eg 5 and 7mm external diameter
Capillary tubing
Plastic tubing, eg 5mm and 7mm bore
Hoffman's screw burette clips
Mohr's spring burette clips
Spirit level
Protractors, set squares
Magnetic compass
Filter papers — coarse, eg Whatman No.1

b. Collecting equipment

Pond-dipping nets
Plastic bowls — yellow or white, for sorting animals, etc
Polythene bags
Sweep net
Towel
Sieves and strainers, eg household type plastic strainers soil sieves
Secateurs

c. Containers

Plastic boxes, transparent, various sizes
Polythene bags
Polythene sheeting — use it to line a box and make temporary aquarium, miniature garden, etc
Empty plastic detergent bottles
Jam jars, sweet jars, etc
Aquaria
Petri dishes, or similar ones; plastic containers
Test-tubes and test-tube brush
Plant pots — various sizes in plastic, pottery, etc.
Square plastic washing up bowl
Plastic bucket
Enamel pie-dishes
Paper cups, foil cake cases
Acetate sheets to make insect cages

d. Support apparatus

Clamp stand and clamp
Tripod stands, wire gauze and
heat resistant mats, metal tongs
'G' clamps

e. Sources of heat, light, power

Candles and night lights
Spirit burner
Electric torches — several sizes
Dry batteries — 1½v to 6v — bulbs,
bulb holders, wire, switches

EXAMPLE: light and colour —
bicycle lamps and torches prism, lenses
mirrors, plane, convex, concave
coloured Cellophane or plastic dye
Kaleidoscope
sunglasses, etc

f. Materials for specific studies

EXAMPLE: magnetism —
horse shoe magnets
bar magnets
rod magnets
disc magnets
pocket compass
magnetic rubber, etc.

2. Tools and materials for constructing things

Children often need to make their own apparatus or models. For this they need a few tools, and suitable materials.

Suggestions are given below.

Tools
Adjustable spanner — small
Bradawl
Cold chisel — small
Drill and bits in suitable sizes

File 6in, flat
'G' clamps
Hack-saw
Hammer
Pincers
Pliers
Punch
Screwdrivers
Tinsmith's snips — straight bladed, Gilbow safety pattern
Small vice

Materials
Wood offcuts
Balsa wood
Dowel rod — several sizes
Wood strip, square section in suitable sizes

Pegboard offcuts, etc
Nails and screws, assorted
Nuts and bolts, assorted
Adhesives
Wood, plastic, or metal construction sets
Adhesive tape
Waverley clips

A stout table or bench for the children to work on is a great advantage.

3. Materials for recording and communication

When children come to record or communicate their findings, it is particularly important to put at their disposal a wide range of attractive materials. Not only does this stimulate their desire to communicate, and increase their pleasure in doing so, but it enables them to learn about the properties of different materials and gradually, with the teacher's help, to choose the best means of communicating whatever they have to say. The teacher may discuss with individuals, or groups, all the possible ways in which they may do this eg by writing, mathematical representation, painting, or models before leaving them to decide for themselves which it will be.

The following list is not meant to be exhaustive, but simply to indicate the range of materials to which the children might have free access.

a. Paper

Assorted sizes, colours and types will be needed.

White drawing paper
Black paper
Sugar paper — assorted colours
Manila — assorted colours
Tissue paper — assorted colours
Brown paper
Squared paper — several sizes and rulings
Gummed paper squares — assorted colours
Gummed paper discs — assorted colours
Postcards
Newsprint — roll

b. Colouring and sketching materials

Poster paint
Powder paint
Felt-tipped pens
Chalks
Pastels
Crayons
Charcoal
Felt-tipped pens
Brushes — several sizes
Coloured inks

c. Fabrics

An assortment of colours and textures will be found useful. Hessian, velvet, corduroy, lace, sewing cotton, wools, tapes, ribbons.

d. Adhesives

Balsa cement, gum, cold water paste, all purpose adhesive, etc.